

An Introduction to the Aerosol Microphysical Model GISS-MATRIX

Susanne Bauer, Dorothy Koch
Surabi Menon
Douglas Wright, Bob McGraw

NASA/GISS & Columbia University
Lawrence Berkeley National Laboratory
Brookhaven National Laboratory

Contact: Susanne Bauer, email: sbauer@giss.nasa.gov
phone: 212 678 5610

MOTIVATION

The GISS model used to calculate only the mass concentrations of the following aerosols: Sulfate, Nitrate, Black and Organic Carbon, Sea Salt and Mineral Dust. No information about the **number concentration** and only few information on **aerosol size** and **internal mixing** was available. The high importance of these quantities, to simulate the direct and indirect aerosol effect on climate, is our motivation to develop a microphysical aerosol module for our climate model, suitable to perform long climate simulations, as well as high resolution simulations, to analyze field studies and study air quality.

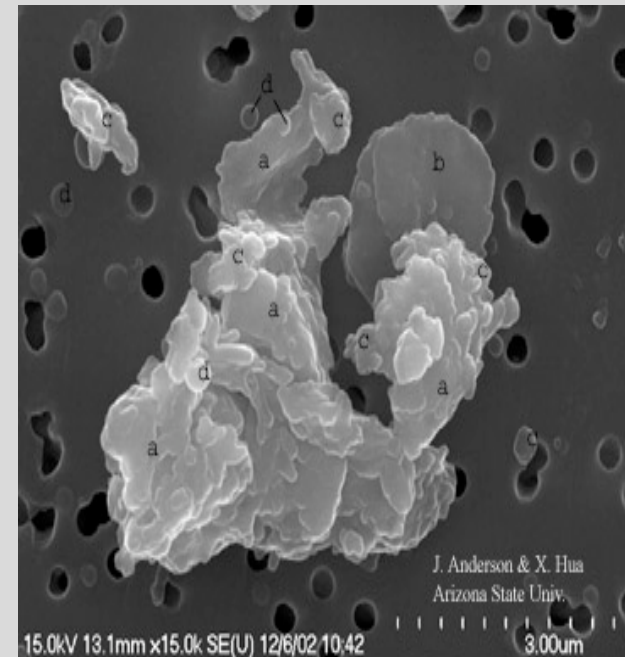


Photo taken by J. Anderson,
Arizona State University

Link to ASP:

Due to the high complexity of our simulations regarding the chemical, physical and optical properties of aerosols, we are very interested in collaborating with ASP scientist to compare our simulations with observations and high resolution model results.

Due to an injury I'm not able to personally attend the meeting but please feel free to contact us.

MODEL DESCRIPTION: GISS ModelE

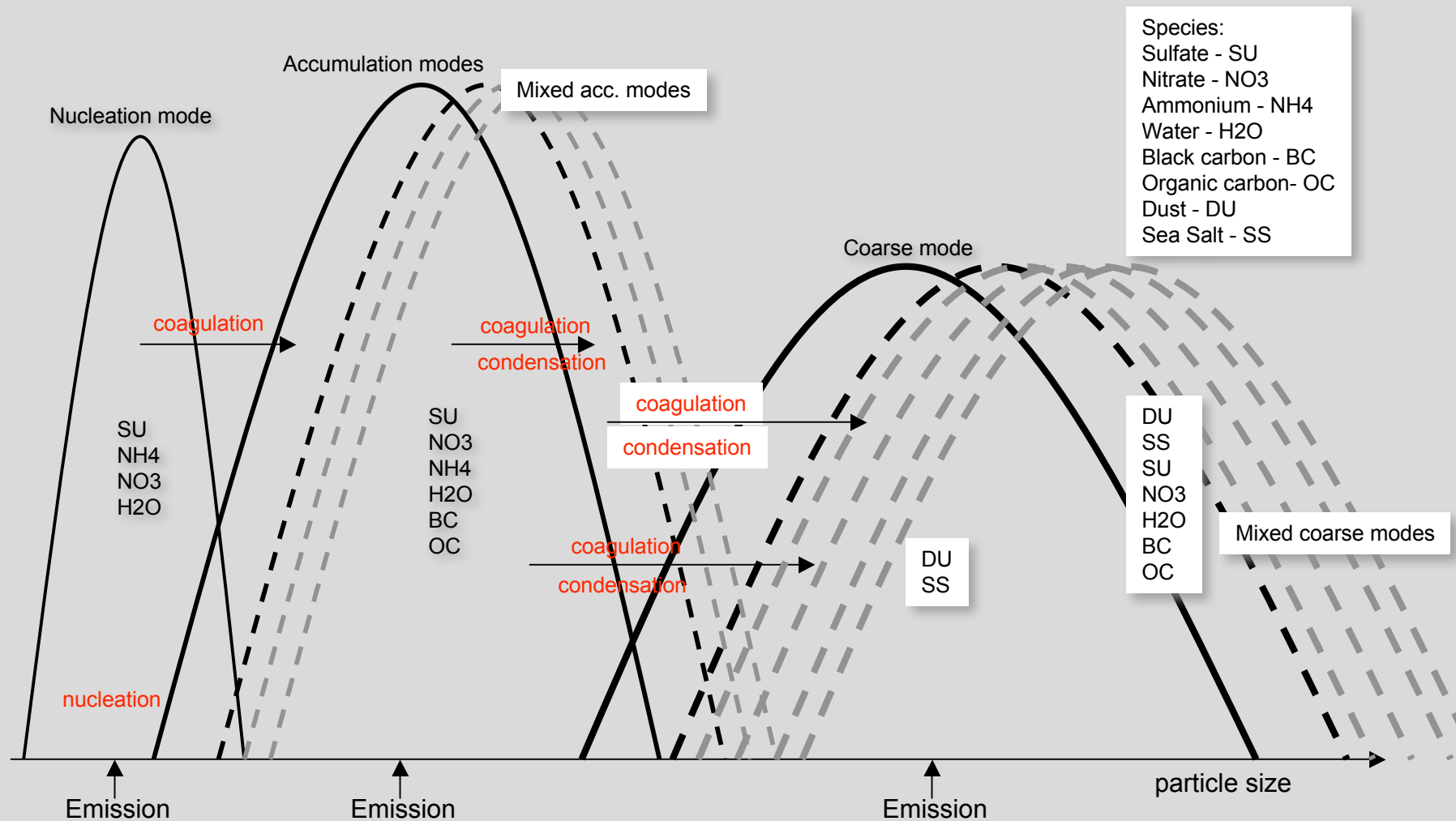
GISS ModelE is the latest version of the **G**oddard **I**nstitute for **S**pace **S**tudies climate model. ModelE is getting developed towards an Earth System Model, including dynamical ocean, vegetation, ice sheet dynamics, atmospheric chemistry, etc.

Standard resolutions are $4 \times 5^\circ$ and $2 \times 2.5^\circ$ for fast climate runs. A $1 \times 1^\circ$ resolution is currently under development for air quality and field study analysis. Various horizontal resolutions can be employed; the range spans from a coarse 20 layer model up to a 54 layer model, well representing the troposphere and the stratosphere.

MODEL DESCRIPTION: MATRIX

The Aerosol Microphysical Model (GISS-AMP) is based on the Quadrature Methods of Moments Scheme (QMOM) [McGraw 1998], where aerosol properties are represented by the moments of their size distribution. The aerosols are represented by several modes, including primary modes that receive particulate emissions, secondary modes formed mostly by coagulation of primary modes, and a mixed mode that includes all aerosol constituents. Looking at the relative populations of the various modes, the overall mixing state of the aerosol is characterized, as well as the progress toward a well-mixed state. The aerosol species are sulfate, nitrate, ammonium, water, black carbon (BC), organic carbon (OC), mineral dust, and sea salt. The four inorganic species are associated with all modes.

Design of the Microphysical Aerosol Model



Parameterizations:

Nucleation:

- **Jaecker-Voirol and Mirabel, 1989:** Binary H_2SO_4 - H_2O nucleation rate: J
- **Vehkamäki et al., 2002:** Binary H_2SO_4 - H_2O nucleation rate: J
- **Napari et al., 2002:** Ternary H_2SO_4 - H_2O - NH_3 nucleation rate: J
- **Turco et al., 1998:** Ion-ion recombination nucleation rate: J
- **Kerminen and Kulmala, 2002:** Conversion function F_{KK02} : $J_p = F_{\text{KK02}} J$
- **Eisele and McMurry, 1997:** New particle formation rate: $J_p = K[\text{H}_2\text{SO}_4]^n$

Coagulation

Treatment of coagulation coefficients K_{ij} :

- CONST constant K_{ij} from fixed lognormal for each mode
- DYNAM variable K_{ij} from variable lognormals with fixed standard deviations, temperature

Thermodynamic module

Gas-particle mass transfer

- **Metzger et al. 2005** EQSAM (highly parameterized, very fast)
- **Nenes et al. 1998** ISORROPIA (less parameterized, fast enough for CMAQ)

Preliminary Model Results:

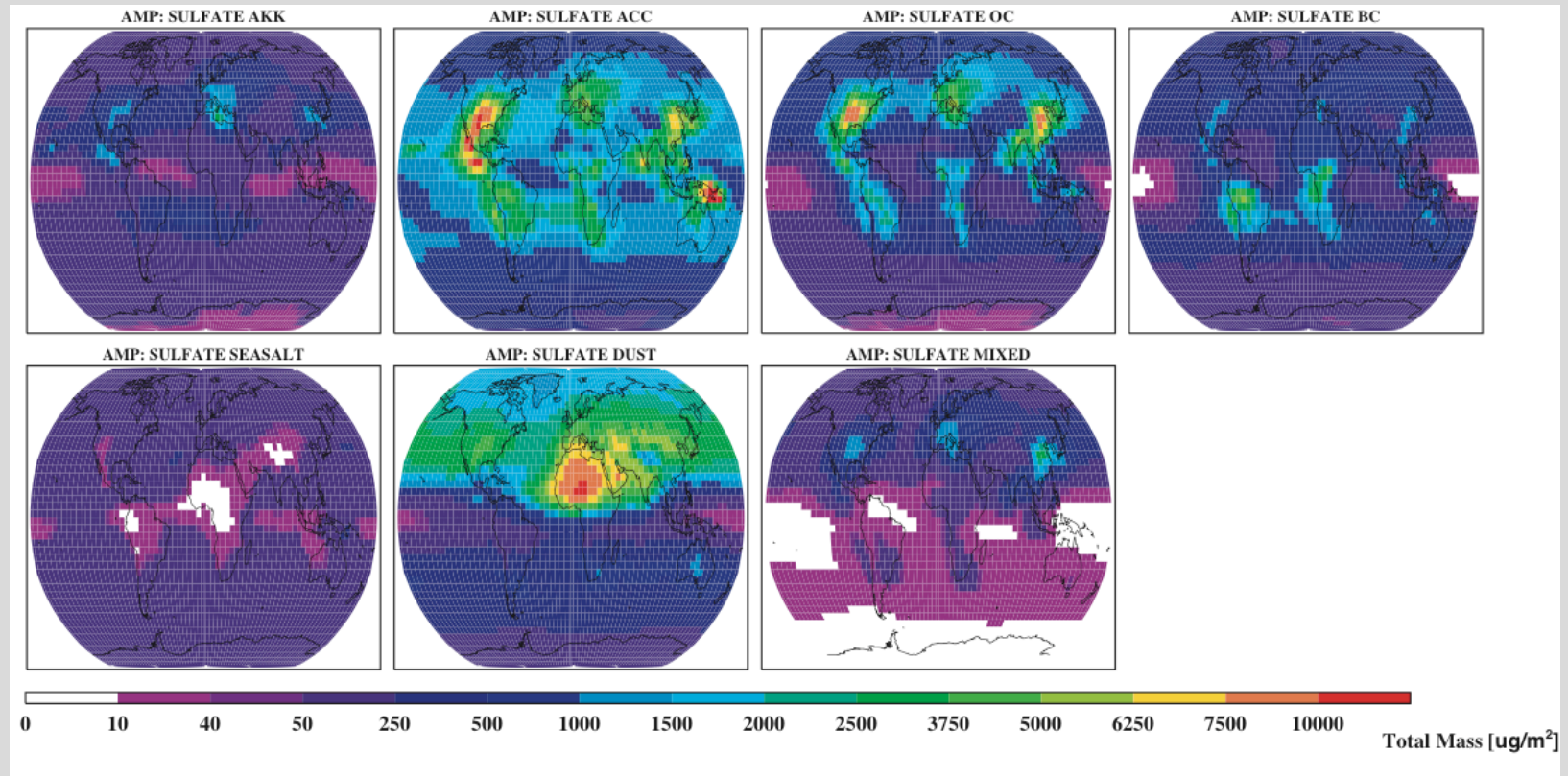


Figure 1: Column mean mass concentrations of sulfate material, as present in the aiten mode (AKK), accumulation mode (ACC), attached to organic carbon, black carbon, sea-salt, mineral dust and tertiar mixtures. Units are in [mg/m^2]

Preliminary Model Results:

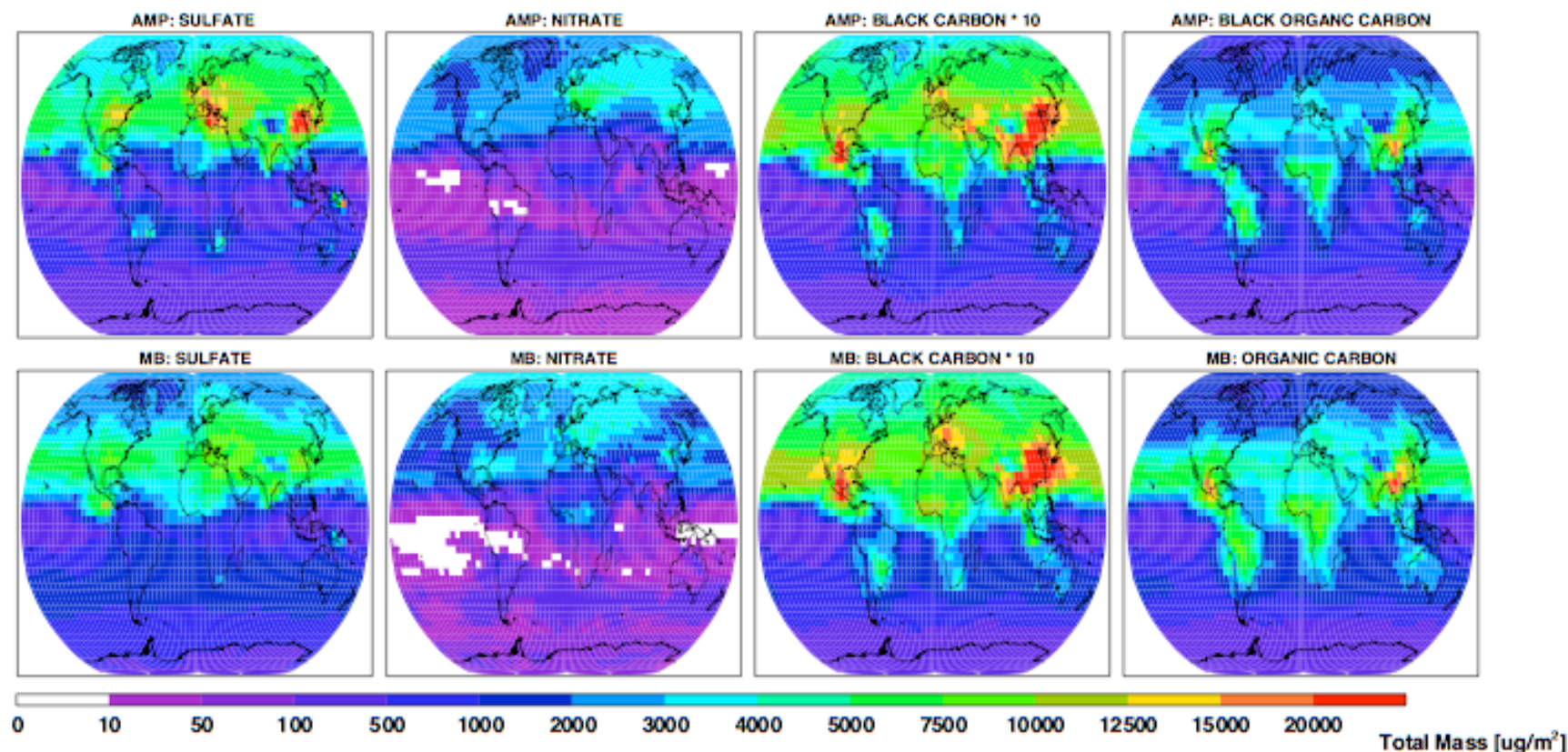


Figure 2: Column mean mass concentrations of ammonium sulfate, ammonium nitrate, black carbon and organic carbon, as simulated with the MATRIX scheme (upper panel) and the 'old' mass based aerosol model (lower panel). Units are in $[\text{mg}/\text{m}^2]$. Please note, black carbon concentrations are multiplied by a factor of ten.

Scheme for aerosol-cloud interactions:

New ways to represent cloud and precipitation processes

Use a two-moment bulk scheme:

Based on version adapted for MM5 and being implemented in CAM (Morrison et al 2005)

We treat number concentration (N) and mixing ratio (q) of 4 classes: cloud drop, cloud ice, rain, snow.

We also represent interactions between them: Melting, freezing, collection, sedimentation, autoconversion, accretion, evaporation, condensation, deposition, sublimation.

Droplet activation parameterized as a function of supersaturation, vertical velocity and diabatic heating rate besides aerosol properties (number concentration, solubility, size, type, etc.)

Need to treat dispersion that can be diagnosed from predicted moments or prognosed independently.

Discussion of Preliminary Model results:

One year of model simulation was carried out with the new MATRIX scheme and the 'old' mass based aerosol scheme. The same emission and deposition rates were used for both simulations. The differences between the aerosol loads in Figure 2 are caused only by the microphysics. For example much higher sulfate concentrations are simulated in the polluted regions, lower black carbon concentrations in Europe etc. Larger differences will appear when all processes in the GCM will be coupled to MATRIX, for example through impacts of the chemical composition of the internally mixed particles on the removal rates, feedbacks through clouds and radiation.

However, the real challenge of our project will be the evaluation of the physical properties of the simulated aerosols.

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